

New directions in the detection of polarized light

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Introduction

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Polarization sensitivity, including particularly polarization vision, is an area of sensory neuroscience that has received a surge of interest in recent years. Aside from the esoteric Haidinger's brush, the human experience of this type of visual capability is only possible through filters or other artificial aids, such as polarizing sunglasses, cameras and machine vision. As a result, we tend to think of this type of light detection as an oddity restricted to small sections of the animal kingdom, perhaps useful for navigation and water surface detection in a few insects. This exclusive view is quite wrong and, as we discover more about the uses of polarization sensing, it is becoming apparent that most animal groups are capable of detecting and using this type of light for a number of different tasks.

The papers in this volume detail largely new biological discoveries (some placed in the context of reviews of previous work) and also descriptions of the polarizing properties and visual ecology of environmental light. Engineering solutions and potential applications also permeate several contributions, including one specifically on this subject [1], but even here the applications are based on concepts inspired by biological systems. Within the core biological papers, there are descriptions of retinal anatomy, neurophysiological studies, behavioural evidence and characterization of polarization signals. All of these involve aspects of how animals perceive and make use of polarized light. Animals studied are also broad-ranging with both vertebrates and invertebrates, and terrestrial and aquatic habitats, represented.

As editors, we deliberately chose a comparative view and asked authors to cross boundaries in order to provide what we hope is a thought-provoking assemblage of research into different areas of polarized light detection. Many of the articles collected here had their origins in a small international conference entitled 'New Directions in Research on Polarization of Light', held at Voyages Heron Island Resort, on The Great Barrier Reef and associated with The University of Queensland's Heron Island Research Station. The conference was generously supported by both the United States Air Force and Navy, among others, and was a superb opportunity to share ideas and new information. Having the presence and participation of researchers and engineers from these sponsoring groups enhanced

the directions and concepts raised during this meeting, and this clearly flows through to this volume of the Royal Society's *Philosophical Transactions B*.

Contributions are arranged in approximate thematic areas, starting with five that examine environmental polarized light distribution, the physics of polarized light and its detection and biological relevance for different tasks. There is a central section on behavioural experimentation where new work is presented on three different insect species: butterflies, beetles and bees. These two areas, physics and behaviour, are bridged by Homberg *et al.*'s [2] elegant study of how the environmental pattern of celestial polarized light is interpreted by the central nervous system. This completes the journey of polarization cues from the environment, through the processing machinery of the central nervous system to resultant behaviours and their relevance in the life of each species. The final section of seven papers is largely concerned with different potential functions of polarization vision and draws from anatomical and behavioural studies as well as optics. Horvath *et al.* [3] polish this and the whole volume off with a fascinating examination of how seafaring Viking navigators apparently used the pattern of polarized light in the sky to navigate, a likely unintentional example of biomimicry.

It is important to recognize that all work presented in this special issue has grown from the inspirational efforts of our predecessors in the field of polarization research, and of these, four—three of whom are still active—are worth specific note in the context of what is presented here. Talbot Waterman [4] provided the grounding work for almost all areas of research covered here. His works on polarized light in atmosphere and ocean, anatomical studies, as well as physiological and behavioural studies are essential reading for any student of this area. Sadly, as this collection of work neared completion, Talbot passed away and this volume is dedicated to his memory. Ruediger Wehner has provided decades of inspiration through patient behavioural observation, careful electrophysiological work and elegant biology, pioneering much of the navigation and functional correlates of anatomy on which many of us base our current methods and ideas. Thomas Labhart's [5] achievements in electrophysiological recording underpin much of what we now understand with regard to central processing and neuronal encoding of polarized light. Tom has kindly agreed to provide a Preface to this volume and was an enthusiastic

One contribution of 20 to a Theme Issue 'New directions in biological research on polarized light'.

participant of the conference on Heron Island. Craig Hawryshyn [6] has pushed the complex frontiers of vertebrate polarization vision and has also covered all aspects we discuss in this volume. Craig (along with Howard Browman) also coordinated a meeting on polarization vision and ultraviolet vision in 2000 and in some respects this volume is an update of that work one decade later.

The supporters of the conference from which this volume is distilled deserve special mention again, not just because they facilitated a very productive meeting, but also because many of them were keen to have representatives there to contribute, discuss and guide the future of this growing area. Specifically they are: the Asian Office of Aerospace Research and Development (AOARD), the Air Force Office of Scientific Research (AFOSR), the European Office of Aerospace Research and Development (EOARD), the Office of Naval Research Global (ONRG), the International Technology Centre–Pacific (ITC–Pac), the University of Queensland (Deputy Vice Chancellor–Research, Faculty of Biological and Chemical Sciences and the Queensland Brain Institute), the University of Maryland, Baltimore County (Biological Sciences). (AFOSR/AOARD/EOARD/ITC–Pac and ONRG support is not intended to express or imply endorsement by the US Federal Government.)

Much of the organization of the conference and also the initial stages of the production of this volume were superbly coordinated by Kylie Greig. Finally, in our recognition of support, Willard Larkin, Programme Manager of Sensory Information Systems within AFOSR, has provided ongoing, enthusiastic support and encouragement to enable much of the work seen in this volume, as well as the conference itself.

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